Jeffrey Pilkington
Flow Visualization
Clouds 1
28 February 2013

Purpose:

This image was taken for the first clouds assignment in flow visualization. I intended to capture the turbulence in the clouds as they came over the flatirons. Since the sky was so blue it was a great opportunity to catch the white edges of the cloud against the deep blue sky. I think the vortices that are apparent in the clouds are really appealing patterns.

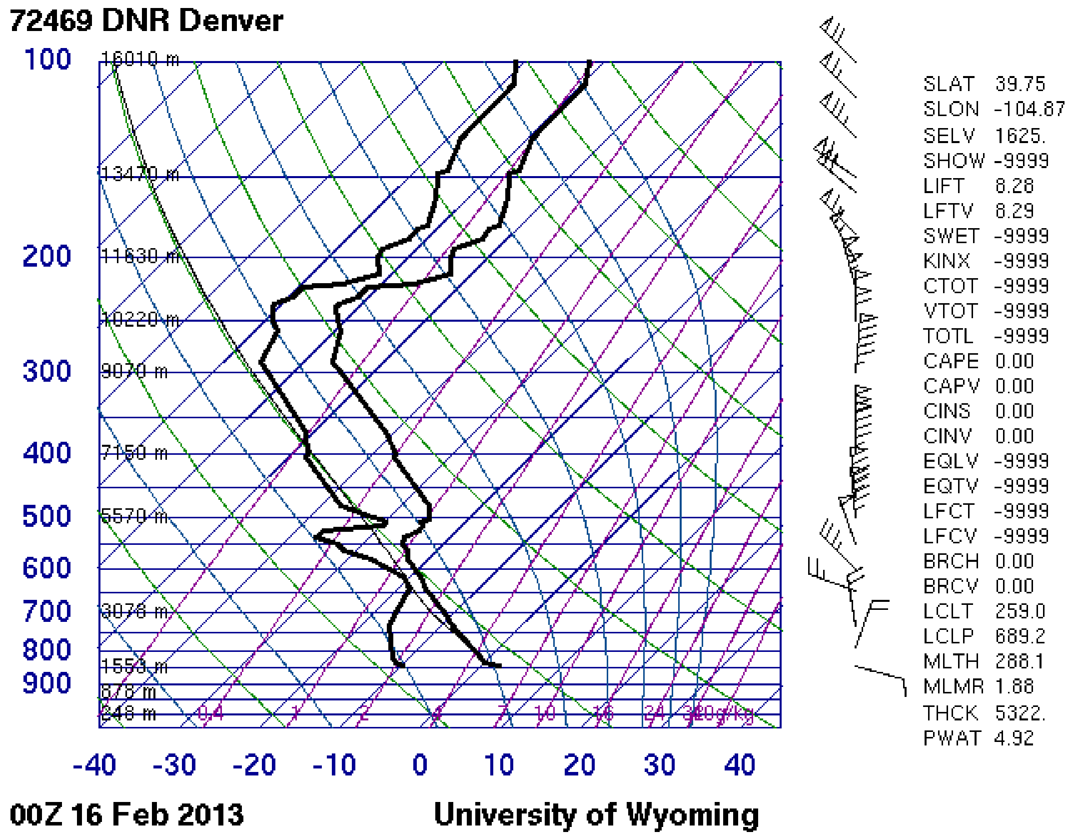
Circumstances:

The image was taken on Feburary 15 2013 at 1pm. I was directly beneath the cloud so the camera was pointed straight up toward the sky. The photo was taken at the intersection of Pleasant St. and Broadway in Boulder Colorado. My chest was pointed directly south; the bottom of the image is the south side of the cloud. The right of the image is west toward the flatirons. The left of the image is the east side going toward Denver and the top of the image is to the north.

Cloud Identification:

The cloud photographed is a strato-cumulus fractus mountain wave cloud. This is an orographic cloud because it is caused by the topography of the area. Air from a stable atmosphere is forced upward as it ascends the face of the mountain. This air near the surface of the earth forces the air above it to move higher. This disturbance causes the air to oscillate as it continues past the mountain. These clouds are generated by atmospheric waves with a wavelength equal to the wind speed divided by the Brunt–Väisälä frequency. [2] The peaks of the oscillation become smaller as the air moves further away until it returns back to equilibrium. When the air rises from these oscillations, the moisture in the air adiabatically cools and the moisture condenses into water or ice. When it descends to the “trough” of the oscillation the water and ice vaporize. The moisture in the air is only visible when it is in liquid or solid form because the light interacts with it and the human eye can perceive this interaction. This is why the “peaks” of the wave are visible as clouds and the “troughs” are not visible. It is common to see several separate clouds that are parallel to the mountain over which they ascended. This phenomenon is very apparent in the Boulder area. These clouds can exist for several hundred kilometers along the boundary between the front range of the Rocky Mountains and the Great Plains. [1] It is postulated that mountain wave clouds can also form because of convection from mountain summits. Researchers monitored the cloud patterns above Green Mountain and found that the air rising from convection created a disturbance in the overhead air that behaved very similar to the disturbance caused by a mountain. [1] Wave clouds are being studied because they may have an impact on the “radiation budget” of the earth. As the vapor rises and condenses it can form water or ice. When the clouds form ice, a wide range of crystal sizes exist. These crystals interact with the impinging radiation from the sun and can alter the amount of radiation that hits the surface of the earth. [2]

At the time the image was photographed, the temperature of the air near the surface was 43 F, the winds were blowing at approximately 4.7 mph from the south. The relative humidity was 38%. The visibility was 10.0 miles. [3] The cloud in the photo is a strato-cumulus fractus mountain wave cloud. [4] In Boulder there is a large pressure gradient across the mountains that causes very high winds, this is especially common in the winter. [5] Windstorms are associated with the mountain wave clouds and they occur more often at night in the winter [1] The night of February 15, also showed this trend with high winds in the evening. The previous day was a fairly stable atmosphere and the temperature was much lower than average this time of year. The day after the photo was taken had high temperatures and high winds. The atmosphere was stable, this is shown from evaluating the skew T diagram. [6] The CAPE is 0 which shows that it is stable. Another way to determine if it is a stable atmosphere is to look at the temperature line, at all times this line is above the adiabat. This means that if a parcel of air was disturbed it would seek to assume its original position. The cloud in the photo likely occurred where the dew point and temperature lines are close to each other. This occurs at approximately 4000 meters. This is about the height of the cloud in the image.



Photographic Technique:

This photo was captured using a Kodak Easyshare z915 digital camera. The image is 3,648 x 2,736 pixels. I tried several combinations of settings to get the photo to show the interesting vortices on the edges of the cloud. I set the shutter speed to 1/500 because the light intensity was quite high. The aperture was f/8.3 to get a greater depth of field. The ISO was set to 100 because the environment was already very bright. It is difficult to estimate the size of the field of view in this image because there is no other size reference. The cloud was approximately 4000m directly above the camera. I would estimate that the field of view is approximately

400x300 meters. The distance from the object to the lens was approximately 4000m this is based on the perceived height in the sky and confirmed using the skew T diagram. Where the dew point and temperature lines are closest is most likely where the clouds were located. The original image was 3,648 x 2,736 pixels. To enhance the turbulent activity on the edges of the clouds I used curves to increase the contrast of the image. I was not concerned with losing the highlights in the center of the clouds because I think the detail in the vortices is the most beautiful part of the image. I was able to successfully bring them out against the deep blue background. There was a light post in the lower left corner of the image, I used Photoshop to paint this out and keep the focus of the image on the clouds. The original (left) and final (right) images are shown in the figure below.

Conclusion:

I was extremely pleased with the result of the photograph. I completely captured the edges of the clouds as I had intended. After several days of shooting I was releived to get the cloud I wanted. The physics behind the cloud is really intriguing and it creates beautiiful patterns. The turbulent flow is apparent on the edges of the clouds. To develop this concept further I would take a picture of the successive cloud waves and then zoom in on the individual cloud. I feel that this would be the best way to demonstrate the physics of the atmosphere.

References:

[1] Worthington, R.M. "Lenticular wave cloud above the convective boundary layer of the Rocky Mountains," Weather 57(2002):87-90.
[2] Baker BA, Lawson RP (2006) In Situ Observations of the Microphysical Properties of Wave, Cirrus, and Anvil Clouds. Wave clouds got their name because they look like waves. Part I: Wave Clouds. Journal of the Atmospheric Sciences: Vol. 63, No. 12 pp. 3160–3185
[3] "WeatherSpark Beta." *Beautiful Weather Graphs and Maps*. N.p., n.d. Web. 28 Feb. 2013.
[4] "The Cloud Collector's Reference Â» Main Types." *The Cloud Collector's Reference Â» Main Types*. N.p., n.d. Web. 28 Feb. 2013.
[5] Wallace, John M., Hobbs, Peter V. Atmospheric Science, and Introductory Survey. San Diego, CA: Academic Press, 1977.
[6] "Atmospheric Soundings." *Atmospheric Soundings*. N.p., n.d. Web. 28 Feb. 2013.